

Qualification Testing of Concentrator PV Modules: Approved Standard, Existing Test Facilities and Preliminary Test Results

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ABSTRACT

Test standards and independent test facilities have been available for years and used extensively for the qualification testing of flat-plate photovoltaic (PV) modules. No such test standards or test facilities were available for the qualification testing of concentrator PV modules. In the current work, a parallel effort was made to develop both test standard and test facilities to test concentrator PV modules. This paper discusses the recently approved Institute of Electrical and Electronics Engineers test standard (IEEE 1513), *Recommended Practice for Qualification of Concentrator Photovoltaic (PV) Receiver Section and Modules*. This paper also describes various unique pieces of test equipment developed at the Arizona State University Photovoltaic Testing Laboratory (ASU-PTL) to test the concentrator PV modules for the design qualification per IEEE 1513 standard. These unique test-equipment items include two-axis trackers, thermal shock chamber and water spray station. In addition, ASU-PTL has been validating the newly developed test method for side-by-side performance testing of test module vs. control module to measure the relative performance degradation of the stressed test module. This work identifies the limitations of the proposed simple dark I-V method for measuring module degradation. Preliminary relative-power measurements have been conducted under various solar irradiance, air mass, and ambient temperature conditions. ASU-PTL has recently initiated a full qualification evaluation per IEEE 1513 for a US manufacturer (Amonix, Inc.) and this initiative is discussed in this paper.

Introduction

Qualification testing of photovoltaic (PV) modules is of great importance to evaluate the modules for their design performance, safety,

and susceptibility to known failure mechanisms. Successful completion of qualification testing and issuance of certification provide a reasonable assurance that the photovoltaic modules of the tested model will perform reliably under field conditions.

Test standards specify a common approach to conduct the qualification testing. For the flat-plate PV modules, IEEE 1262 and IEC 61215/61646 qualification test standards specify the required tests, test procedures and pass criteria. For the concentrator PV modules, no such IEEE or IEC standards were available for the qualification testing. ASU-PTL was mandated through this contract to coordinate all the efforts to ballot an IEEE standard (IEEE 1513) for the qualification testing of concentrator PV modules. In late 2000 the final draft standard was sent out for balloting and on March 17, 2001 the standard was approved by the IEEE Standards Board. This paper provides an overview of this approved standard for the qualification testing of concentrator modules.

ASU-PTL is an independent, accredited testing laboratory and has all the test equipment needed to test and certify flat-plate PV modules per IEEE and IEC standards. This paper describes various unique pieces of equipment and test procedures developed for the extension of the qualification testing to the concentrator PV modules.

Test Standard

The format and test procedures of well-documented IEEE 1262 flat-plate test standard have been predominantly used to develop this new IEEE 1513 concentrator test standard. Major differences between these two test standards are indicated below:

- *Total number of required test samples:* IEEE 1262 testing requires nine modules whereas IEEE 1513 testing requires seven receiver sections and five modules;
- *Eliminated tests:* Mechanical load, surface cut susceptibility, twist and ultra-violet exposure tests have been eliminated in the IEEE 1513 standard;
- *Added tests:* Water spray and off-axis beam damage tests specific to the concentrator modules are added to the IEEE 1513 standard;
- *Modified tests:* To accommodate high temperature softening effects of the concentrating lenses, IEEE 1513 standard offers several options to conduct the thermal cycling and humidity freeze tests, especially related to the reduction of the upper temperature limit of the cycles. Since the field installed concentrator cells may experience thermal shocks due to change in the environmental conditions, the concentrator standard recommends a very high cooling and heating rates (5°C/minute) to test the receiver sections (thermal shock testing).
- *Optional tests:* All the intermediate I-V tests in each sequence are optional diagnostic tests.
- *Diagnostic tests:* Dark I-V method is available as a diagnostic tool for the relative degradation of the performance after each stress test.
- *Alternative electrical performance tests:* IEEE 1262 recommends both indoor and outdoor methods. IEEE 1513 recommends three alternative methods but all of them are outdoor methods.

This approved IEEE 1513 standard serves as the starting point to the development of IEC 62108 concentrator standard [1] and this effort is again being coordinated by ASU-PTL.

Test Equipment

ASU-PTL is extending its test equipment capability to conduct all the tests per IEEE 1513 standard. This capability is specifically extended to the added tests, modified tests, diagnostic tests and the new outdoor electrical performance tests that are mentioned in the previous section.

A special water spray station has been built to evaluate the electrical isolation properties of the concentrator PV modules under wet conditions. Its design construction meets all the UL 1703 test standard specifications, which is required by the IEEE 1513 test standard. Two 2-axis trackers with an in-house fine-tune mechanism have been installed for the off-axis and side-by-side electrical performance testing of the

concentrator PV modules. The side-by-side performance testing of control-module with stressed-module identifies the relative performance loss of stressed module. A 5-kW power supply is used to obtain the dark current-voltage curves and to pass current through the modules during thermal cycle testing. A conventional environmental chamber has been retrofitted to meet or exceed the stringent heating and cooling requirements of the test standard.

Validation of I-V Test Procedures

Validation of side-by-side outdoor performance degradation measurements was carried out using two concentrator PV modules. The relative power outputs of these two modules were monitored over a period of time. The preliminary results indicate that the coplanar alignment of the modules on the tracker platform and aiming the modules for the DNI condition are having more influences on the accuracy of the relative power measurements as compared to the influences from the ambient/cell temperature, air mass and irradiance changes.

The dark I-V method is limited to obtain the absolute performance of a PV module as it requires the short-circuit current and series resistance values of the module under light conditions. However, it is expected to be a simple, cost-effective, yet reliable method for the qualification (relative performance) testing of PV modules [2]. This method essentially quantifies the relative performance degradation of a stressed module from the increase of effective resistance. In this work, the stressed receiver was simulated by adding a few resistors in series to a test receiver. The dark I-V curves were obtained before and after adding the resistors. This work indicates that the cell temperature and bias current levels profoundly influence the accuracy of the test results.

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